DOCUMENT RESUME

ED 328 414 SE 051 889

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TITLE The Effects of Hands-On versus Remediation-Based Biology Preparatory Course Curricula on Performance in Follow-up Biology Courses at the Community College Level.
PUB DATE 90
NOTE 25p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Academic Achievement; *Biology; *College Science; Community Colleges; *Experiential Learning; Inquiry; Laboratories; *Remedial Instruction; Remedial Programs; Science Curriculum; Science Education; *Science Instruction; Teaching Methods; Thinking Skills; Two Year Colleges; Two Year College Students

ABSTRACT

The purpose of this investigation was to compare two different methodological techniques of a biology preparatory course in order to determine which curriculum's methodologies were most effective in preparing biology students for follow-up biology courses as measured by course grades. One was based upon laboratory hands-on experiences and the other upon mathematics and reading remediation. The results show that the hands-on course grades were significantly better than that of the control and the remediation-based groups. The document includes the abstract, introduction, background, student characteristics, a comparison of the two biology curricula, purpose of the study, hypotheses procedures and experimental design, data collection and analysis results, conclusions, discussion and significance, and a list of 13 references, 3 figures, and 7 tables. (KR)

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ED328414

The effects of hands-on versus remediation-based biology preparatory course curricula on performance in follow-up biology courses at the community college level.

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The effects of hands-on versus remediation-based biology preparatory course curricula on performance in follow-up biology courses at the community college level.

ABSTRACT

Two different curricula used in teaching a biology preparatory course were compared to determine their effects on students' performance in follow-up biology courses. One was based upon laboratory hands-on experiences and the other upon mathematics and reading remediation. One-way analyses of variance were used to compare all groups. The two groups did not differ significantly from each other ($p \leq 0.05$) in biology preparatory grades, age, sex, birthplace, years in the United States, type of high school degree, freshman mathematics, reading, and writing skills scores. However, they differed from each other in follow-up biology course grades. Each biology preparatory group was compared with a control group of students. Analyses showed that only the hands-on biology preparatory group was significantly better in follow-up biology course grades when compared with the control group. Analyses of variance were performed comparing follow-up course grades between the hands-on, the remedial, and the control groups. Scheffe contrasts were used to indicate any significant differences between groups. It was found that the hands-on course grades were significantly better than that of the control and the remediation-based groups. In addition, a larger percentage (23.2%) of the hands-on preparatory group passed biology follow-up courses with a grade of C or better when compared with the remediation-based preparatory group (16.1%) and the control.

The effects of hands-on versus remediation-based biology preparatory course curricula on performance in follow-up biology courses at the community college level.

Introduction

This investigation stems from a 1989 study (Biermann and Sarinsky) which focused upon determining the variables which discriminated between pass/fail biology preparatory students at an urban community college. Data indicated mathematics and reading scores as being significantly and positively related to achievement in the biology preparatory course. In addition, it was determined that for those preparatory students who take follow-up courses, the preparatory grade is the best predictor of their follow-up course grades. The study also ascertained that a control group's follow-up course scores were not significantly different from that of the biology preparatory group taught by a remediation-based approach. The outcome was surprising and led to investigation of another approach to teaching the biology preparatory course to determine whether this approach, a hands-on approach, is more effective. Therefore, data were collected concerning the preparatory students taught by the hands-on approach and their follow-up scores were compared with that of the remediation-based group and the control.

A predominant issue in science education involves the pedagogical approaches to instruction. Development of reasoning skills could be linked with concrete, hands-on experiences. The Piagetian approach (1970) suggests that students who reason at the concrete level benefit from hands-on activities. Despite this fact, hands-on activity based elementary science programs

developed in the 1960's and 1970's have fallen out of favor because they are expensive and difficult to secure and maintain. These types of experiences however, lead to increased science achievement and cognitive development (Koballa, 1986). According to Piagetian theory, this enhancement effect is due to the fact that individuals construct their own knowledge based upon their sensory experiences of the world.

Lawson and Renner (1975) indicated that many secondary school students are concrete thinkers and cannot understand abstract subject matter. Underprepared students at the community college level also have the same types of difficulties with abstract concepts (Rothaug, et. al. 1981). These students must be taught in ways that enable them to develop better reasoning skills. In addition, a quantitative study by Shymansky, et. al. (1983) showed that students taught by hands-on methods outperformed students in traditional programs.

Leonard (1989) has stated that "meaningful laboratory instruction in college science courses appears to be distinguished from traditional strategies in at least three ways:

> Students are engaged in a number of the science inquiry processes, such as observing, classifying, measuring, communicating, collecting and organizing data, inferring from observations, hypothesizing, manipulating experimental variables, analyzing data, and drawing conclusions from data.
>
> Students have the opportunity to manipulate experimental materials, thus providing a 'hands-on' experience.
>
> Students learn in an experimental manner specific scientific concepts.."

A course of instruction, according to McDermott, et. al. (1980) should possess emphasis on laboratory, stress reasoning, emphasize the role of examinations and use of homework, and progressively increase student challenges. The course could develop skills in note taking, vocabulary building, using the library, writing term papers and presenting oral reports. Minority group professors might also guest lecture to provide role models. Following participation in a biology preparatory course, many student difficulties should be overcome so that they may be prepared to compete with other students in follow-up biology courses.

Background

A preparatory biology course was instituted at the community college under study because underprepared students were not succeeding in basic anatomy and physiology or general biology courses. The biology preparatory course was developed by faculty consensus in the year 1979. The curriculum for the course changed over subsequent years. One curriculum was developed which emphasized remediation-based materials since it was perceived that there would be:

1. reinforcement of the basic skills which students received in other remedial classes.
2. transfer of skills to the anatomy and physiology or general biology classes.
3. an improvement in the passing rate.

The remediation-based curriculum did not improve the passing rate (Biermann and Sarinsky, 1989). Another curriculum which emphasized the hands-on approach to learning was compared with the remediation-based approach.

The same group of instructors involved in creating the curricula taught both preparatory courses. The follow-up biology courses were instructed by a group which never varied.

Student Characteristics

Students who wished to enroll in general biology or anatomy and physiology courses, and who demonstrated deficiencies in mathematics, reading or writing skills on standardized entrance examinations (Freshman Skills Assessment Tests), were required to first successfully complete a biology preparatory course at the community college studied.

The population for this study consisted of 797 students. They were predominantly female (88%), 43% were born in the United States, while 57% were foreign born. In the latter group, 16% were Haitian, 10% Jamaican, 8% were Virgin Islanders (various islands), and 5% Guyanese, with additional smaller percentages of other nationalities. Thirty-six percent of the students have been in the United States for 10 years or less. In the total group of students, 68% graduated from high school while 30% had taken high school equivalency degrees (GED). A few students had previously attended college (2%).

Comparison of the Two Biology Preparatory Curricula

A comparison of these two curricula showed that each combined discussions with demonstrations, laboratory hands-on experiences, and remediation skills. In the curriculum emphasizing a laboratory hands-on approach the students spent 27 hours performing basic scientific measuring, graphing, and developing laboratory and experimental skills. These skills included identifying and demonstrating the correct and safe use of laboratory equipment, scientific methodology, designing experiments, collecting and organizing data, and drawing conclusions from data. Only 15 hours were utilized for these activities with the remediation-based curriculum. In addition, 19 of the 20 hours of discussion-with-demonstrations were devoted to the laboratory experiences with the hands-on curriculum, whereas only 9 of 19 hours were expended on the same activities with the remediation-based curriculum.

The latter curriculum was developed with an increased emphasis on remediation of basic skills such as; enhancement of vocabulary, reading comprehension, library techniques, arithmetic computations, and other skills. The students spent 14 hours of class time practicing these skills and were assigned additional work at home. Ten of the 19 hours of discussion-with-demonstrations were devoted to remediation. In comparison, the hands-on curriculum appropriated one hour of class time and one hour of discussion for remediation. Figures I and II summarize comparisons of the two different curricula.

Insert Figures I and II

Purpose of Study

Studies comparing different methodological techniques may not show significant differences in student outcomes as many of them are not performed longitudinally. The intent of this investigation was to perform such a study in order to determine which curriculum's methodologies were most effective in preparing biology students for follow-up biology courses as measured by course grades.

Hypotheses

H_1 The hands-on biology preparatory group will perform significantly better than the remediation-based biology preparatory group as measured by follow-up biology course grades.

H_2 The hands-on curriculum biology preparatory group will perform significantly better than the control group in upper level biology courses as measured by course grades.

Procedures and Experimental Design

The investigation undertaken was of ex post facto, non-experimental design. Two full academic years of data were collected for students enrolled in the biology preparatory course. In addition, data were collected for a control group. This group was composed of students who enrolled directly into the general biology or anatomy and physiology courses without having taken the required biology preparatory course.

A. Data Collection

Information concerning all groups included students' reading, writing and mathematics skills scores, years in the United States, birthplace, type of high school degree, and sex. Also collected were students' preparatory grades and their initial and best follow-up biology grades. The initial grades were those achieved after attempting the follow-up biology course for the first time. Their best grade represented the highest grade achieved by a student irrespective of whether they repeated the course. Course grades are composite variables which incorporate examinations, quizzes, laboratory practicals and orals as well as written work. Information concerning collection and determination of Freshman Skills Assessment scores may be obtained in the authors' previous study (Biermann and Sarinsky, 1989).

B. Data Analysis

All hypotheses were tested at the 0.05 level of significance. One-way analyses of variance were performed comparing the hands-on biology preparatory group with the remediation-based group as well as both biology preparatory groups with the control. Analyses of variance were performed comparing course grades for the hands-on biology preparatory group with the remediation-based group and the control. Scheffe contrasts were used to indicate any differences between groups.

Results

Figure III is a summary flow chart and comparison of the biology preparatory students (hands-on and remediation-based) and the control. When the three groups were compared for follow-up biology course grades, the remediation-based and control groups showed significantly lower ($p=0.05$) grades than the hands-on group. For the hands-on group, 48% of the students passed with grades of A,B, or C. This represents 23.2% of the initial group. The percentage of A,B, or C grades for the remediation-based group was 37%, which represents 16% of the initial group. The passing rate for the control group was 38.2%.

Insert Figure III

One-way analyses of variance comparing the hands-on curriculum group (n=406) with the remediation-based curriculum group (n=323) demonstrated that the two groups did not differ significantly from each other in biology preparatory grades or any of the other variables except for initial and best follow-up biology course grades, with the hands-on group performing significantly better ($p \leq 0.05$) than the remediation-based group (Table I).

Insert Table I

Tables II and III compared the control group (n=68) with both curricula. The control group was not significantly different from the remediation-based group in any of the variables studied including follow-up biology initial and best grades. However, when this same control group was compared with the hands-on group, the two groups were significantly different ($p \leq 0.05$) in follow-up biology initial grade. The hands-on group outperformed the control group.

Insert Tables II and III

The analysis of variance shown in Table IV which compared both curricula and the control for initial follow-up biology course grades showed a significant difference ($p \leq 0.008$) between the groups. The Scheffe contrast seen in Table V pinpointed the significant difference ($p \leq 0.05$) between the hands-on group and the control. The analysis of variance seen in Table VI compared both curricula and the control for best follow-up course grade and illustrated a significant difference ($p \leq 0.02$) between both curricula and the control. The Scheffe contrast in Table VII showed that the hands-on curriculum best grades were significantly better ($p \leq 0.05$) than that of the remediation-based curriculum.

Insert Tables IV, V, VI, and VII

Conclusions

Hypotheses 1 and 2 were accepted. The biology preparatory group utilizing the hands-on approach was significantly better prepared for follow-up biology courses as measured by course grades when compared with the remediation-based group and the control. Since the one-way ANOVA's showed that the two groups were not significantly different from each other in any of the other variables, the differences shown might be attributable to the characteristics of the curriculum. The results of the analyses of variances supported this conclusion.

Discussion and Significance

The hands-on curriculum appeared to better prepare students for follow-up biology courses when compared with the remediation-based curriculum. Students in the hands-on curriculum group performed better in subsequent biology classes because the techniques used in the curriculum foster the intellectual and practical skills necessary for mainstreaming. Students also developed self-confidence in their abilities to adequately compete with their peers. Therefore, the curriculum based upon hands-on experiences of a concrete nature, appeared to work better with underprepared students.

The significances of this study in terms of its impact on science education are that:

1) it demonstrates the need for follow-up studies of different methodological approaches.
2) it focuses on the positive impact on student outcomes of science process based hands-on approaches to teaching biology.
3) it illustrates the fact that science instructors cannot always expect to "reach" all underprepared students over a relatively short instructional interval. A single course taught over a 12 week period cannot always erase deficits in students' backgrounds which they have accumulated over a period of many years.
4) an increase in the passing rate of 7% in follow-up courses is a significant, though not a dramatic change. A recent report of the United States National Science Foundation (1980) determined that only 22% of students who completed a college baccalaureate degree were categorized as scientifically literate. The 23.2% passing rate observed in this study may be within the range of optimum results for a group characterized by academic deficiencies. It remains for this institution and others to continue longitudinal studies of this kind.

Leonard (1989) indicates that

> Recent research on investigative learning approaches in college science laboratory courses looks encouraging. Much more development of laboratory curricula using inquiry approaches and research which experimentally compares them to existing approaches is still needed. There is a definite trend toward wider use of inquiry laboratory strategies in college and university science courses. The use of such strategies is justified by recent research.

Roth (1989) attempted to define methods and goals for elementary science instruction. She embraced a conceptual change perspective for enhancing science learning. College students could also benefit from the conceptual change perspective which incorporates hands-on experiments along with application opportunities. New instructional models should be investigated more fully.

With respect to science education in general, it might be advisable for instructors at all levels of education to consider reinstitution and refinement of hands-on approaches in the teaching of science classes.

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Shymansky, J.A., Kyle, W.C., Jr. and Alport, J.M. (1982) How effective were the hands-on science programs of yesterday? Science and Children. 20(3), 14-15.

Figure I

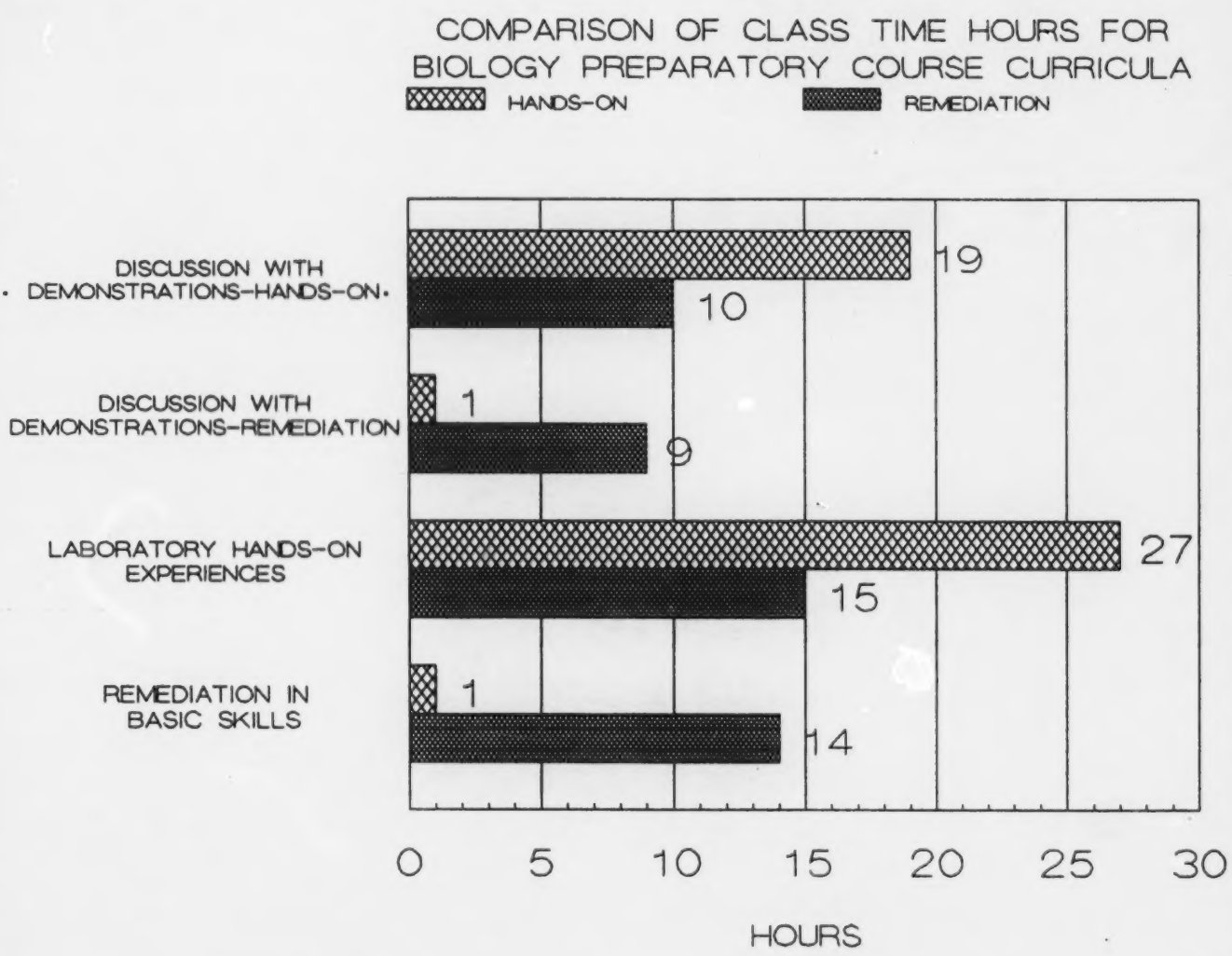

COMPARISON OF CLASS TIME HOURS FOR
BIOLOGY PREPARATORY COURSE CURRICULA
HANDS-ON
REMEDIATION
DISCUSSION WITH
DEMONSTRATIONS-HANDS-ON
19
10
DISCUSSION WITH
DEMONSTRATIONS-REMEDIATION
1
9
LABORATORY HANDS-ON
EXPERIENCES
27
15
REMEDIATION IN
BASIC SKILLS
1
14
0
5
10
15
20
25
30
HOURS

Figure II

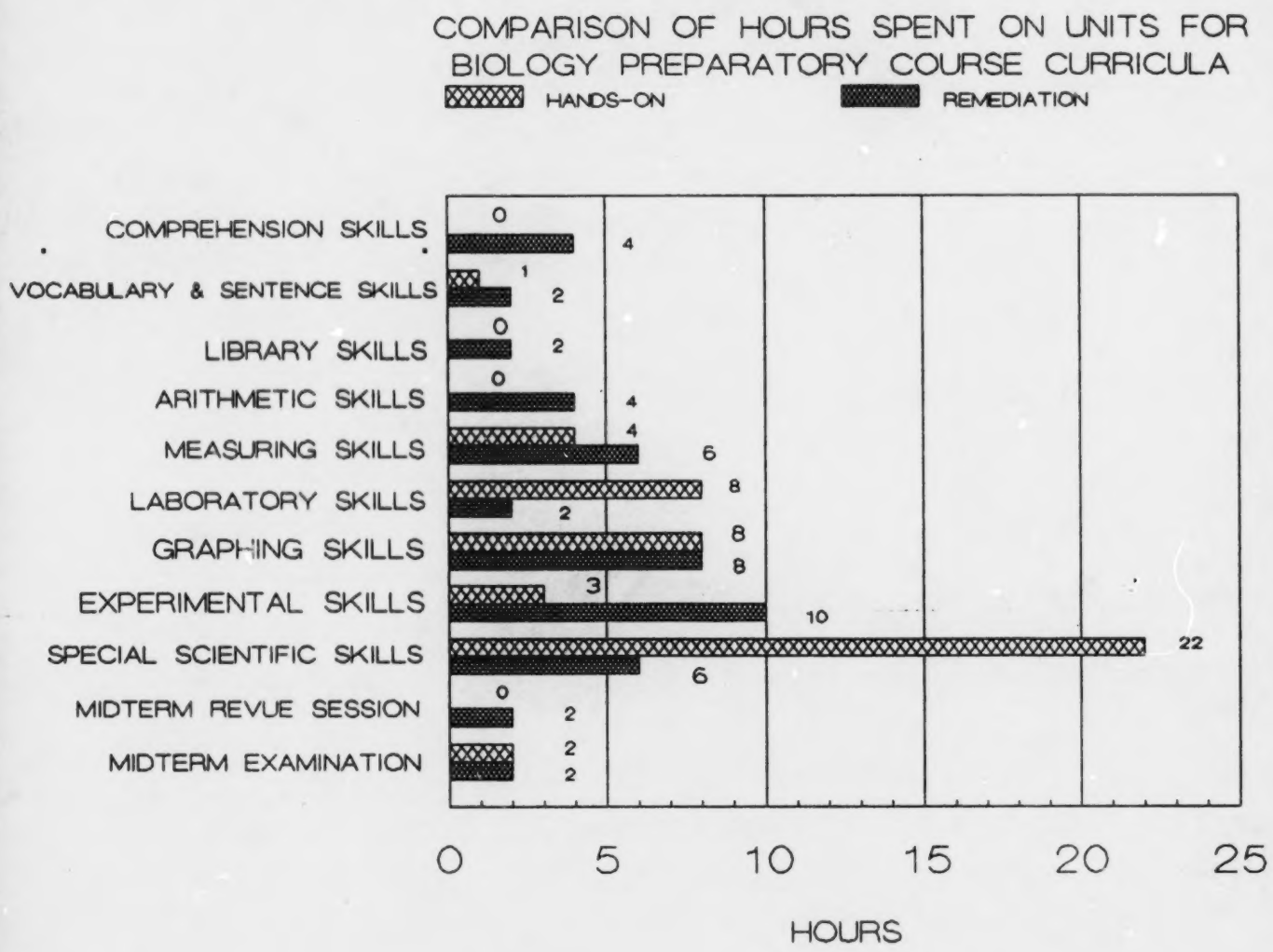
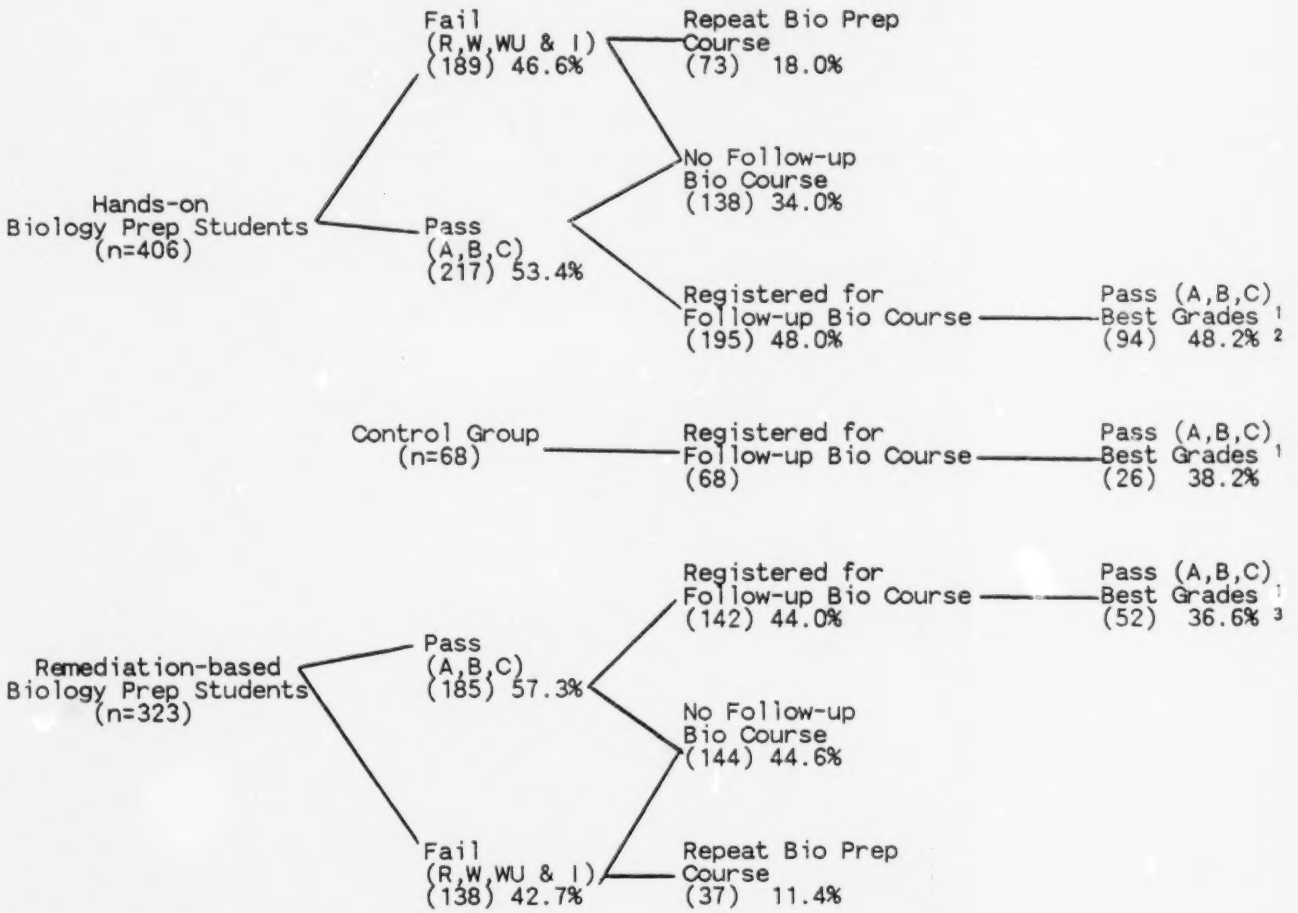

COMPARISON OF HOURS SPENT ON UNITS FOR BIOLOGY PREPARATORY COURSE CURRICULA
HANDS-ON
REMEDIATION
COMPREHENSION SKILLS
VOCABULARY & SENTENCE SKILLS
LIBRARY SKILLS
ARITHMETIC SKILLS
MEASURING SKILLS
LABORATORY SKILLS
GRAPHING SKILLS
EXPERIMENTAL SKILLS
SPECIAL SCIENTIFIC SKILLS
MIDTERM REVUE SESSION
MIDTERM EXAMINATION
0
4
1
2
0
2
0
4
4
6
8
2
8
8
3
10
22
6
0
2
2
2
0
5
10
15
20
25
HOURS

Figure III
Summary Flow Chart and Comparison of the Biology Preparatory Students and the Control Group


Hands-on Biology Prep Students (n=406)
Fail (R,W,WU & I) (189) 46.6%
Repeat Bio Prep Course (73) 18.0%
No Follow-up Bio Course (138) 34.0%
Pass (A,B,C) (217) 53.4%
Registered for Follow-up Bio Course (195) 48.0%
Pass (A,B,C) Best Grades [1] (94) 48.2% [2]
Control Group (n=68)
Registered for Follow-up Bio Course (68)
Pass (A,B,C) Best Grades [1] (26) 38.2%
Remediation-based Biology Prep Students (n=323)
Pass (A,B,C) (185) 57.3%
Registered for Follow-up Bio Course (142) 44.0%
Pass (A,B,C) Best Grades [1] (52) 36.6% [3]
No Follow-up Bio Course (144) 44.6%
Fail (R,W,WU & I) (138) 42.7%
Repeat Bio Prep Course (37) 11.4%

[1] Includes students who may have achieved grade after repeating the course.
[2] Represents 23.2% of the Initial Hands-on (n=406) Biology Preparatory Students.
[3] Represents 16.1% of the Initial Remediation-based (n=323) Biology Preparatory Students.

Table 1
Summary of One Way Analysis of Variance Between Hands-on Based Group (n=406) and Remediation-based Group (n=323)

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Age					
Between groups	1	5.40	5.40	0.08	0.7773
Within groups	686	46271.60	67.45		
Total	687	46277.00			
Sex					
Between groups	1	0.00	0.00	0.01	0.9331
Within groups	717	74.95	0.10		
Total	718	74.95			
Birthplace					
Between groups	1	11.44	11.44	1.10	0.2952
Within groups	648	6756.47	10.43		
Total	649	6767.91			
Years in United States					
Between groups	1	2.27	2.27	0.02	0.8910
Within groups	598	72098.65	120.57		
Total	599	72100.88			
H.S. or G.E.D.					
Between groups	1	0.00	0.00	0.01	0.9407
Within groups	676	170.67	0.25		
Total	677	170.68			
Mathematics Skills Score					
Between groups	1	13.20	13.20	0.24	0.6230
Within groups	707	38586.73	54.58		
Total	708	38599.92			
Reading Skills Score					
Between groups	1	44.01	44.01	1.61	0.2047
Within groups	698	19059.71	27.31		
Total	699	19103.72			
Writing Skills Score					
Between groups	1	1.41	1.41	2.34	0.1264
Within groups	670	403.80	0.60		
Total	671	405.21			
Biology 10 Grade					
Between groups	1	0.60	0.60	0.23	0.6353
Within groups	727	1948.14	2.68		
Total	728	1948.75			
Biology 11/13 Initial Grade					
Between groups	1	12.61	12.61	5.49	*0.0197
Within groups	334	767.36	2.30		
Total	335	779.97			
Biology 11/13 Best Grade					
Between groups	1	15.82	15.82	6.88	*0.0091
Within groups	334	768.16	2.30		
Total	335	783.97			

* $p \leq 0.05$

Table 11
Summary of One Way Analysis of Variance Between Hands-on Based Group (n=406) and Control (n=68)

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Age					
Between groups	1	5.49	5.49	0.09	0.7589
Within groups	444	25872.72	58.27		
Total	445	25878.21			
Sex					
Between groups	1	0.01	0.01	0.10	0.7553
Within groups	469	50.09	0.11		
Total	470	50.10			
Birthplace					
Between groups	1	3.68	3.68	0.28	0.5948
Within groups	403	5231.52	12.98		
Total	404	5235.19			
Years in United States					
Between groups	1	0.01	0.01	0.00	0.9937
Within groups	388	45473.65	117.20		
Total	389	45473.66			
H.S. or G.E.D.					
Between groups	1	0.01	0.01	0.04	0.8403
Within groups	430	112.37	0.26		
Total	431	112.38			
Mathematics Skills Score					
Between groups	1	34.40	34.40	0.62	0.4311
Within groups	453	25089.58	55.39		
Total	454	25123.98			
Reading Skills Score					
Between groups	1	49.71	49.71	1.87	0.1727
Within groups	446	11887.75	26.65		
Total	447	11937.46			
Writing Skills Score					
Between groups	1	0.00	0.00	0.00	0.9605
Within groups	423	255.76	0.60		
Total	424	255.76			
Biology 11/13 Initial Grade					
Between groups	1	16.45	16.45	7.26	*0.0075
Within groups	260	589.01	2.27		
Total	261	605.45			
Biology 11/13 Best Grade					
Between groups	1	7.57	7.57	3.26	0.0724
Within groups	260	604.41	2.32		
Total	261	611.97			

* $p \leq 0.05$

Table III
Summary of One Way Analysis of Variance Between Remediation-based Group (n=323) and Control (n=68)

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Age					
Between groups	1	1.04	1.04	0.02	0.9041
Within groups	372	26529.42	71.32		
Total	373	26530.45			
Sex					
Between groups	1	0.01	0.01	0.13	0.7243
Within groups	382	40.48	0.11		
Total	383	40.49			
Birthplace					
Between groups	1	14.51	14.51	1.59	0.2082
Within groups	367	3350.37	9.13		
Total	368	3364.88			
Years in United States					
Between groups	1	0.61	0.61	0.01	0.9417
Within groups	324	36660.81	113.15		
Total	325	36661.42			
H.S. or G.E.D.					
Between groups	1	0.01	0.01	0.03	0.8645
Within groups	370	86.17	0.23		
Total	371	86.18			
Mathematics Skills Score					
Between groups	1	14.25	14.25	0.24	0.6235
Within groups	378	22322.32	59.05		
Total	379	22336.58			
Reading Skills Score					
Between groups	1	10.54	10.54	0.38	0.5382
Within groups	380	10556.43	27.78		
Total	381	10566.97			
Writing Skills Score					
Between groups	1	0.51	0.51	0.89	0.3475
Within groups	377	215.22	0.57		
Total	378	215.72			
Biology 11/13 Initial Grade					
Between groups	1	1.48	1.48	0.72	0.3982
Within groups	208	429.30	2.06		
Total	209	430.78			
Biology 11/13 Best Grade					
Between groups	1	0.12	0.12	0.05	0.8222
Within groups	208	503.13	2.42		
Total	209	503.25			

* $p \leq 0.05$

Table IV
Analysis of Variance for Biology 11 - 13 Initial Grade for the Hands-on and Remediation-based Curricula and Control

Source	D.F.	Sum of Squares	Mean Squares	F Value
Between groups	2	21.92	10.96	4.92*
Within groups	401	892.83	2.23	
Total	403	914.76		

* $p \leq 0.008$

Table V
Scheffe Contrast for the Biology 11 -13 Initial Grade for the Hands-on and Remediation-based Curricula and Control

	N	Mean	S.D.	S.E.	Differences Between
Hands-on	194	1.66	1.55	0.11	Hands on > Control*
Remediation	142	1.27	1.47	0.12	
Control	68	1.09	1.37	0.17	

* $p \leq 0.05$

Table VI
Analysis of Variance for Biology 11 - 13 Best Grade for Hands-on and Remediation-based Curricula and Control

Source	D.F.	Sum of Squares	Mean Squares	F Value
Between groups	2	18.13	9.06	3.88*
Within groups	401	937.85	2.34	
Total	403	955.97		

* $p \leq 0.02$

Table VII
Scheffe Contrast for the Biology 11 -13 Best Grade for the Hands-on and Remediation-based Curricula and Control

	N	Mean	S.D.	S.E.	Differences Between
Hands-on	194	2.11	1.50	0.11	Hands-on > Remed-based*
Remediation	142	1.67	1.54	0.13	Remed-based < Hands-on*
Control 68	1.72	1.59	0.19		

* $p \leq 0.05$